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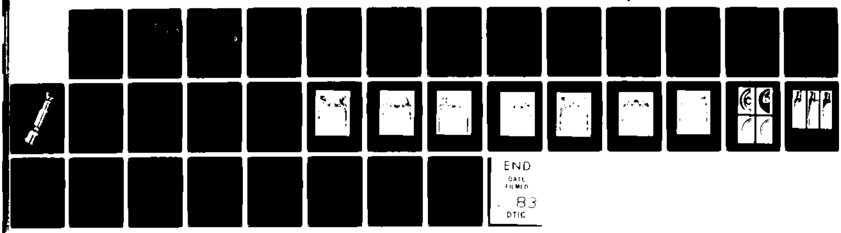

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ENGINEERING DEVELOPMENT ESTABLISHMENT

STRESS ANALYSIS OF 7.62 mm

CARTRIDGE CASES

BY

N.D. OLVER

PUBLICATION EDE-13/82

Prepared and issued under my direction.

(P.J.A.Evans)
Brigadier
Head of Establishment

MARIBYRNONG VICTORIA

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REPORT ON

STRESS ANALYSIS OF 7.62 MM CARTRIDGE CASES

BY

N.D. OLVER

SUMMARY

The report details the results of an investigation into the stress distribution in the head of a 7.62 mm NATO cartridge case using a three dimensional photoelastic stress freezing technique. Three variants of the round were examined and it was found that a slightly increased internal radius in the interior of the cartridge case significantly reduced the stresses in the head of the case.

Maribyrnong
October 1982

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REPORT ON

STRESS ANALYSIS OF 7.62 MM CARTRIDGE CASES

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INTRODUCTION

1. In recent years there have been a number of occasions where Australian made 7.62 mm ammunition has not met proof requirements and has not been accepted for use by Army.

2. As part of the investigation of these failures a photoelastic study of the three-dimensional stress distribution in the cartridge case was undertaken by Engineering Development Establishment (EDE) to determine if any improvement in the strength of the cartridge case could be achieved without changing either the specified external geometry or significantly reducing the internal volume of the case. This report describes the "stress-freezing" techniques used in the investigation and the results obtained.

3. The procedure of three dimensional stress analysis by stress freezing has been widely used by many workers in the field.[1,2]. Briefly the procedure utilizes the fact that some photoelastic materials have a two-phase structure with each phase having a different softening temperature and quite different photoelastic properties. When a model fabricated from such a material is heated to the lower softening temperature and then loaded, all the load is effectively carried by the unsoftened phase. If the model is then slowly cooled to ambient temperature while still under load, the softened phase will reharden, "freezing" the unsoftened phase in its loaded condition even when the external load is removed. This effect (holding of the phase in its loaded condition) will continue even if the model is cut up into sections.

4. The stress distribution in a three-dimensional model may thus be examined by cutting "slices" of uniform thickness from the model after it has been subjected to the temperature/load conditions detailed above and examining the photoelastic pattern of the slice in a polariscope. The procedure of stress analysis of the slice is considerably simplified by selecting the plane of the slice such that it has no shear stress across it, that is, normal to an axis of symmetry, normal to holes etc, if this is done the slice may be

1. Field J.E. and Kirkwood W.F. "Stress concentrations around multiple windows in a high pressure vessel". Experimental Mechanics June 1971

2. Frotch M. ed Symposium on Photoelasticity MacMillian Company New York NY - 1963

analysed to determine directly two of the principal stresses on the surface of the model. The third principal stress may be determined by cutting "sub-slices" from the slice and analysing the sub-slice in a polariscope. This aspect is discussed in more detail in para 12.

METHOD

Models

5. Eight models of the 7.62 mm cartridge case were machined from cast blocks of epoxy resin (Araldite D) hardened with triethylene tetramine (Araldite HY951). This material does not require the complicated preparation, heat treatment and the long curing time used by Leven[3] and hence is very much easier to use. Extensive testing has been carried out on this material, using discs under diametral compression to verify the stress optic properties at high temperatures and the ability of the material to accurately retain stress patterns for up to three years after stress freezing.

6. Two models of each of the following variants of the NATO 7.62 mm cartridge case were manufactured from cast epoxy resin. They were:

a. as per EDE Drawing (A) 83-7, (Models 1 and 2),

b. as per 6a but with reduced radii in the Primer cavity, (Models 3 and 4),

c. as per 6a but with an increased radius in the cartridge cavity, and a reduced bridge thickness (Models 5 and 6),

d. as per 6a but with an increased radius in the cartridge cavity (Models 7 and 8).

7. Models 6c and d were designed to reduce the severe stress concentration on the internal surface of the case. Fig 2 details the dimensions of each model tested.

8. One model of each version was installed in turn in the fixture shown in Figs 3 and 4, which simulated the weapon chamber, and subjected to the stress freezing temperature/time cycle under the following conditions:

a. Differential pressure across model, 207 kPa. This was achieved by subjecting the outside of the case to a a near vacuum and the inside to a pressure of 207 kPa. This was necessary to correctly scale the ratio of the pressures acting on the actual cartridge case, ie 380 MPa atmospheric pressure.

b. Protrusion of the model from the end of the chamber, 18.79 mm. This represents the maximum dynamic head space likely to occur in the GP MG M60 multiplied by the model scale factor (3.286).

3. Leven M.M. "Epoxy resins for photoelastic use" Photoelasticity, Pergamon Press - 1963

c. Head of the model fully supported by the screwed plug which represents the breech block (bolt) of the weapon.

9. Stress freezing of the second model of each version was carried out under the same conditions, the only difference being that the head of the case was unsupported to simulate "bolt-bounce" in an automatic weapon. The model was retained in the fixture by a collar machined on the body of the case as shown in Fig 2.

10. In all cases a primer moulded from silicon rubber was used to simulate the metal primer normally fitted to the cartridge case.

ANALYSIS

Model Slicing

11. Eight slices, lettered A to H inclusive, were cut from each model as shown in Fig 5 and 6.

Stresses

12. The tangential stresses on the free boundary of each slice were determined from the photoelastic stress pattern observed when the slice was set up in a transmission polariscope as shown in Fig 7. In this configuration the observed pattern is a function of the stresses σt and σr in the plane of the slice and is independent of σh which is parallel to the light path. The magnitude of a tangential stress σt at the boundary, where σr is known, may be easily calculated from the known photoelastic properties of the model material. The hoop stresses at selected locations on the free boundary of each slice were determined in a transmission polariscope as shown in Fig 8. In this configuration the observed pattern is determined by the stress σr and σh and is independent of σt which is parallel to the light path. Fig 9 shows the location of the sub-slices cut from the radial slices.

RESULTS

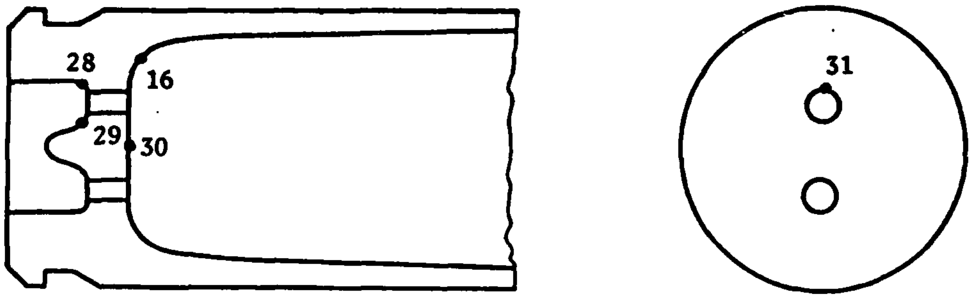
13. Fig 10 details the locations on the model at which the (principal) boundary stresses were determined. To enable a comparison to be made of the relative state of stress at different locations on the surface it is necessary to combine these three stresses into an equivalent yielding stress according to the Von Mises yielding criteria:

$$\sigma eq = \sqrt{\frac{(\sigma_1 - \sigma_2)^2 + (\sigma_1 - \sigma_3)^2 + (\sigma_2 - \sigma_3)^2}{2}}$$

14. The photoelastic stress patterns for the radial slice (Slice A of Fig 5) for each of the models are shown in Fig 11 and 17 incl, the figures along the boundary of each pattern are the Von Mises equivalent stress. Fringe orders for the photoelastic stress pattern are shown on the fringes. The photoelastic stress pattern for the transverse slices, slices C, E, F, G and H of Fig 5 and 6, from the first model are shown in Fig 18 and 19. The pattern for these

stresses for all the other models are almost identical and are not included in this report.

15. The stresses measured at each point are tabulated in Annex A and a summary of the maximum combined stress in each model at the most highly stressed positions is given in Table 1. Model No 8 was damaged during the stress freezing process and results for this model were not obtained.



FIRE HOLES

FIG 1 - LOCATION OF POSITION NUMBERS
(Used in Table 1)

TABLE 1 - SUMMARY OF MAXIMUM COMBINED STRESS IN EACH MODEL (kPa)
(S = Supported U = Unsupported)

Position No	Model 1 S	Model 2 U	Model 3 S	Model 4 U	Model 5 S	Model 6 U	Model 7 S	Model 8 U
16	813	861	855	889	696	682	668	Refer Para 15
28	654	586	724	655	786	786	655	
29	698	620	751	717	558	558	434	
30	524	455	654	551	855	827	668	
31	779	730	779	758	758	779	730	

DISCUSSION

16. General

The most highly stressed areas on the cartridge case occurred at Positions 16, 28, 29, 30 and 31 which are detailed in Fig 1 and 10. Models 5, 6, 7 and 8 were produced with a slightly larger radius at Position 16 to reduce the severe stress concentration in this area. Models 5 and 6 had a quasi - "hemi-spherical" head which resulted in a thinner bridge thickness. Models 7 and 8 retained the bridge thickness of the first four models. All models tested had the same diameter fire holes and all models had approximately the same combined stress at the edge of the fire hole. (Position 31). The following sub-paragraphs discuss the stress in each of the four case geometries tested:

a. Models 1 and 2 (as per EDE(A)83-7).
The highest combined stress occurred at Position 16, which is where yielding of the case would be expected to first occur. The effect of leaving the head of the cartridge case unsupported was to increase the combined stress at Position 16 and to reduce the combined stress at all other locations in the head.

b. Models 3 and 4 (as per EDE(A)83-7 with reduced radii in primer cavity).
The combined stress at each position in these models was higher than the corresponding position on Models 1 and 2, this effect can probably be attributed to the increased stress concentration of the smaller radii in the primer cavity in these models. As in Models 1 and 2 the effect of leaving the head unsupported is to increase the combined stress at Position 16 and to reduce it at all other positions in the head.

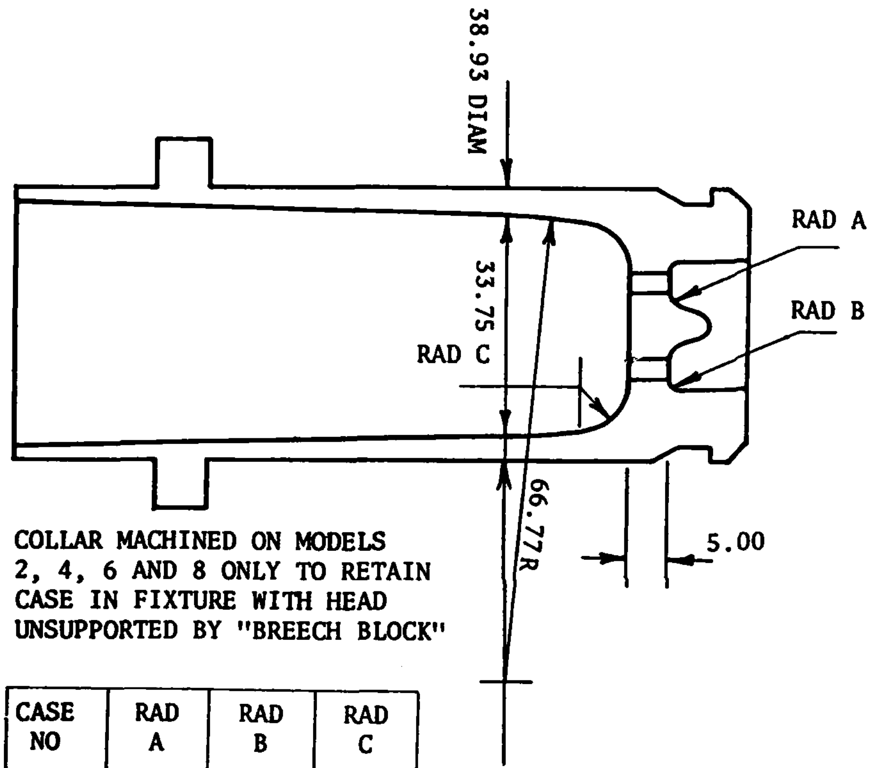
c. Models 5 and 6 (as per EDE(A)83-7 but with an increased radius in the cartridge cavity and thinner bridge).
The highest combined stress occurred at Position 30 in the centre of the bridge, the combined stress at Position 16 being significantly reduced by the larger internal radius, however since the combined stress at Position 30 is nearly equal to the combined stress at Position 16 on Models 1, 2, 3 and 4 this model could not be expected to be any stronger. The effect of leaving the head unsupported was to either reduce or leave unchanged the combined stress in the model.

d. Model 7 (as per EDE(A)83-7 but with an increased radius in the cartridge cavity).
This model showed the best overall distribution of combined stress with a significant reduction of the stress concentration at Position 16.

CONCLUSION

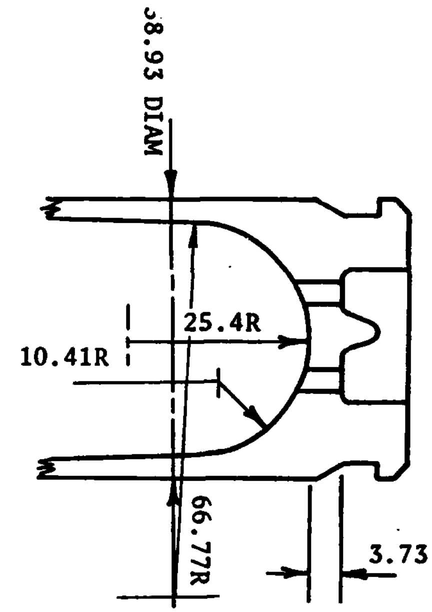
17. Stress analysis of the 7.62 mm cartridge case using 'stress-freezing techniques' has shown that a significant increase in strength could be possible by making a minor change involving an increase in the internal radius at the base of the propellant chamber in the case.

18. This modification would not reduce the internal case volume by more than 1%, and it offers one possible practical approach to solving the problem of cartridge case failure.



COLLAR MACHINED ON MODELS 2, 4, 6 AND 8 ONLY TO RETAIN CASE IN FIXTURE WITH HEAD UNSUPPORTED BY "BREECH BLOCK"

CASE NO	RAD A	RAD B	RAD C
1, 2	0.81	0.81	5.00
3, 4	0.41	0.41	5.00
5, 6	0.81	0.81	
7, 8	0.81	0.81	10.41



INTERNAL HEAD RADII FOR CASES NO 5 AND 6

NOTES:

1. DIMENSIONS SHOWN ARE MODEL DIMENSIONS FOR ACTUAL CASE DIMENSIONS DIVIDE BY MODEL SCALE FACTOR (3.286)

2. ALL DIMENSIONS NOT SHOWN CONFORM TO DIMENSIONS GIVEN ON ADE(A)83-7.

3. DIMENSIONS ARE IN MILLIMETRES.

FIG 2 MODEL CARTRIDGE CASE DIMENSIONS

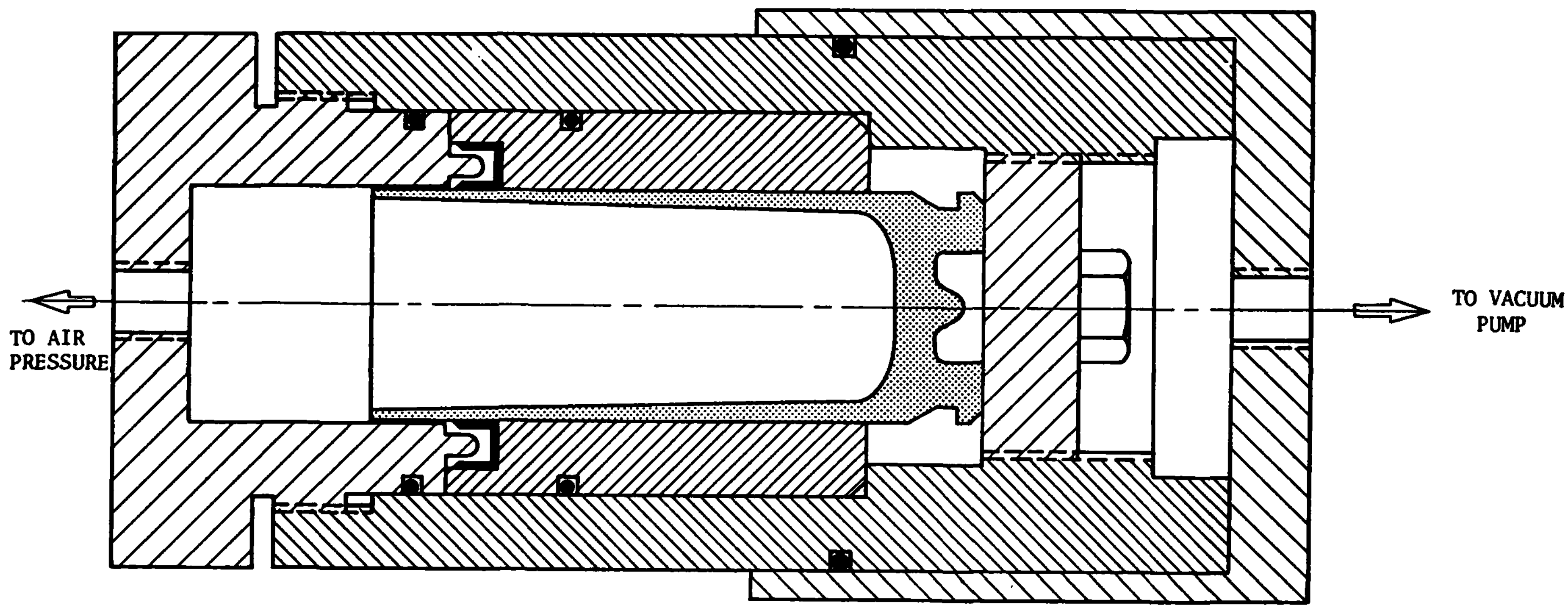


FIG 3 SCHEMATIC OF STRESS FREEZING FIXTURE

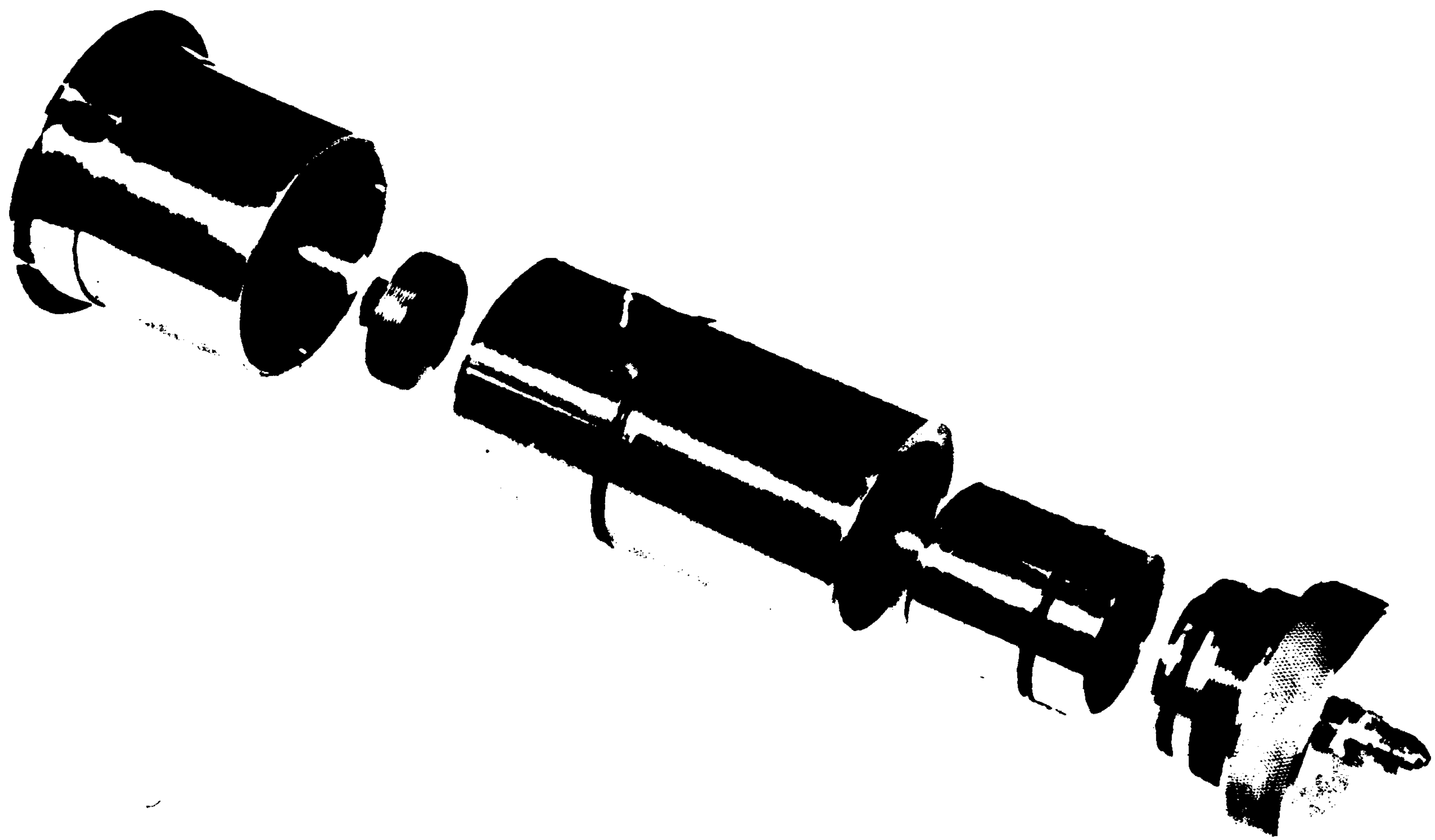


FIG 4 STRESS FREEZING FIXTURE

7059A

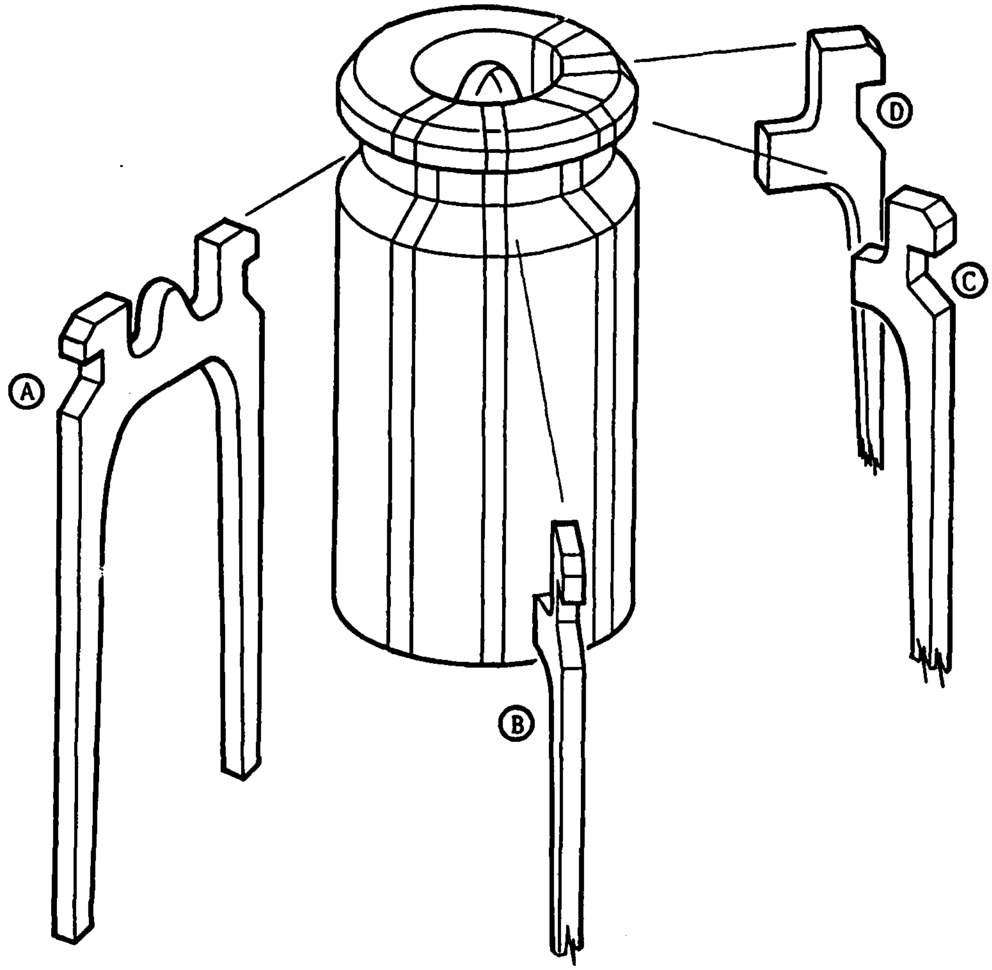


FIG 5 LONGITUDINAL SLICES FROM MODEL

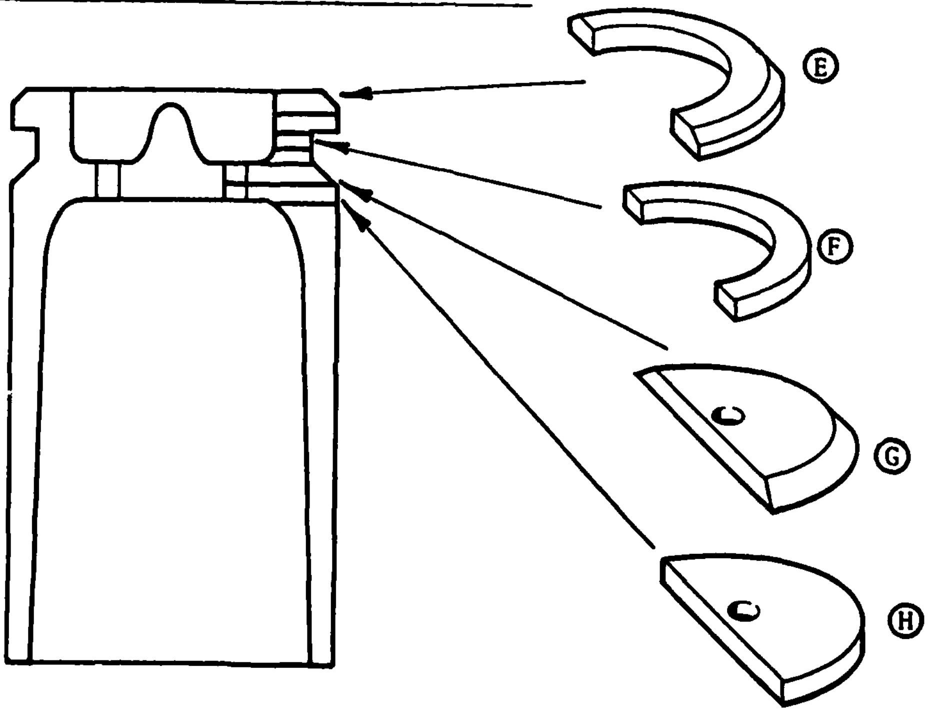


FIG 6 TRANSVERSE SLICES FROM MODEL

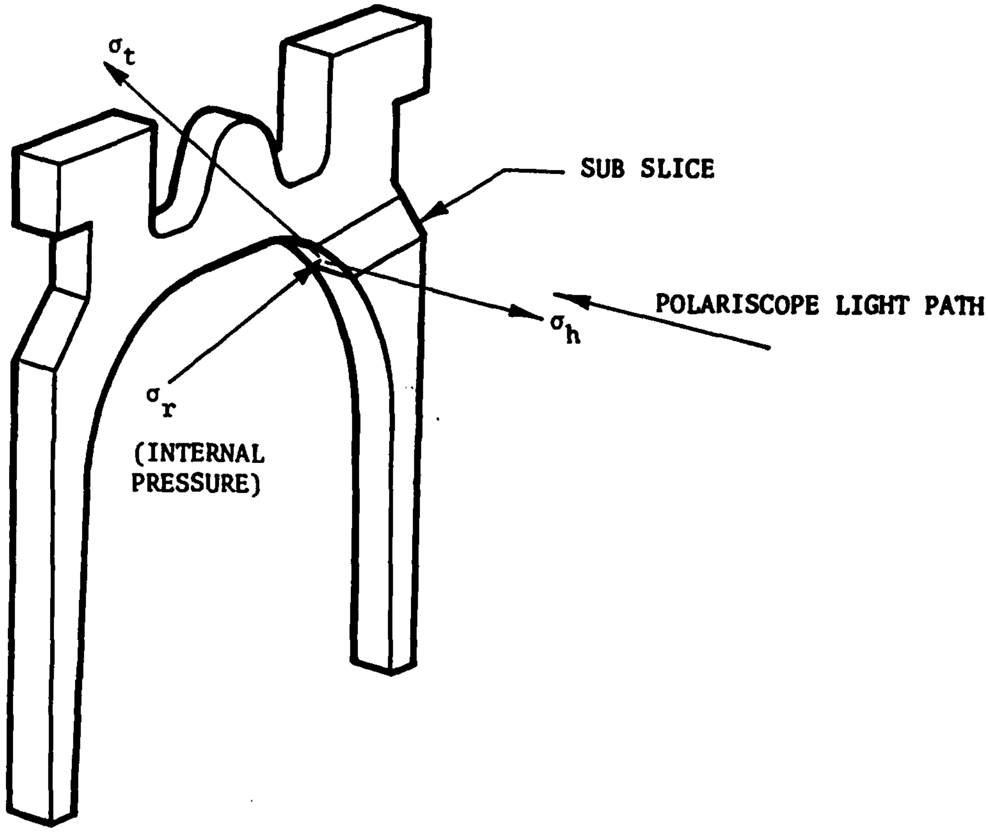


FIG 7 DETERMINATION OF BOUNDARY TANGENTIAL STRESS σ_t

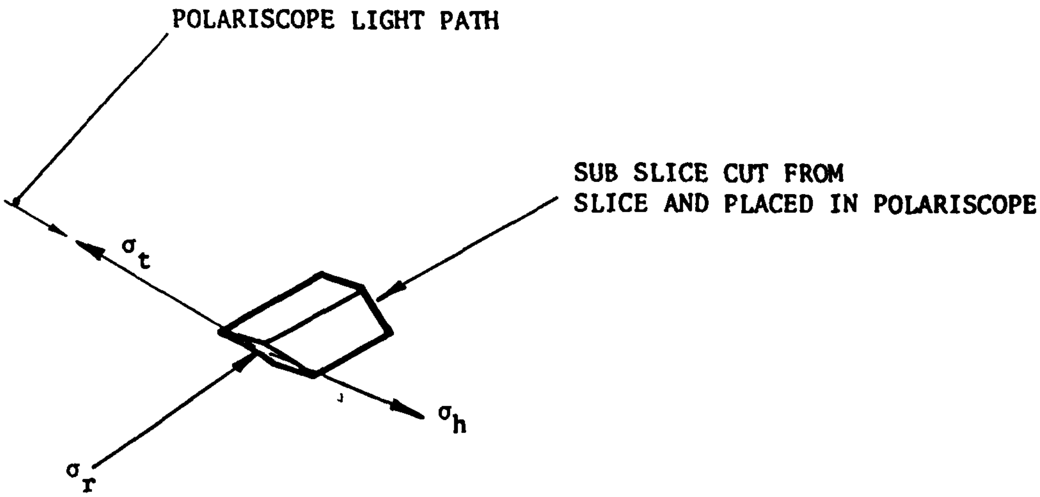


FIG 8 DETERMINATION OF HOOP STRESS AT BOUNDARY

(For clarity the sub slice cut from the slice shown in Fig 6 is shown in its original position)

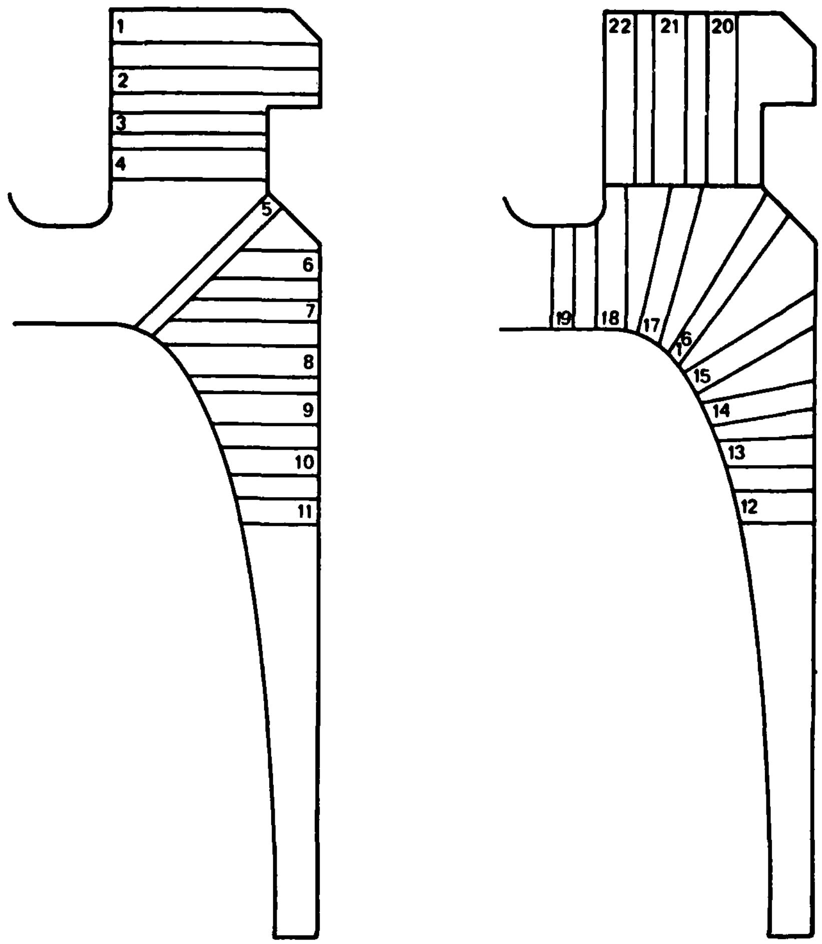
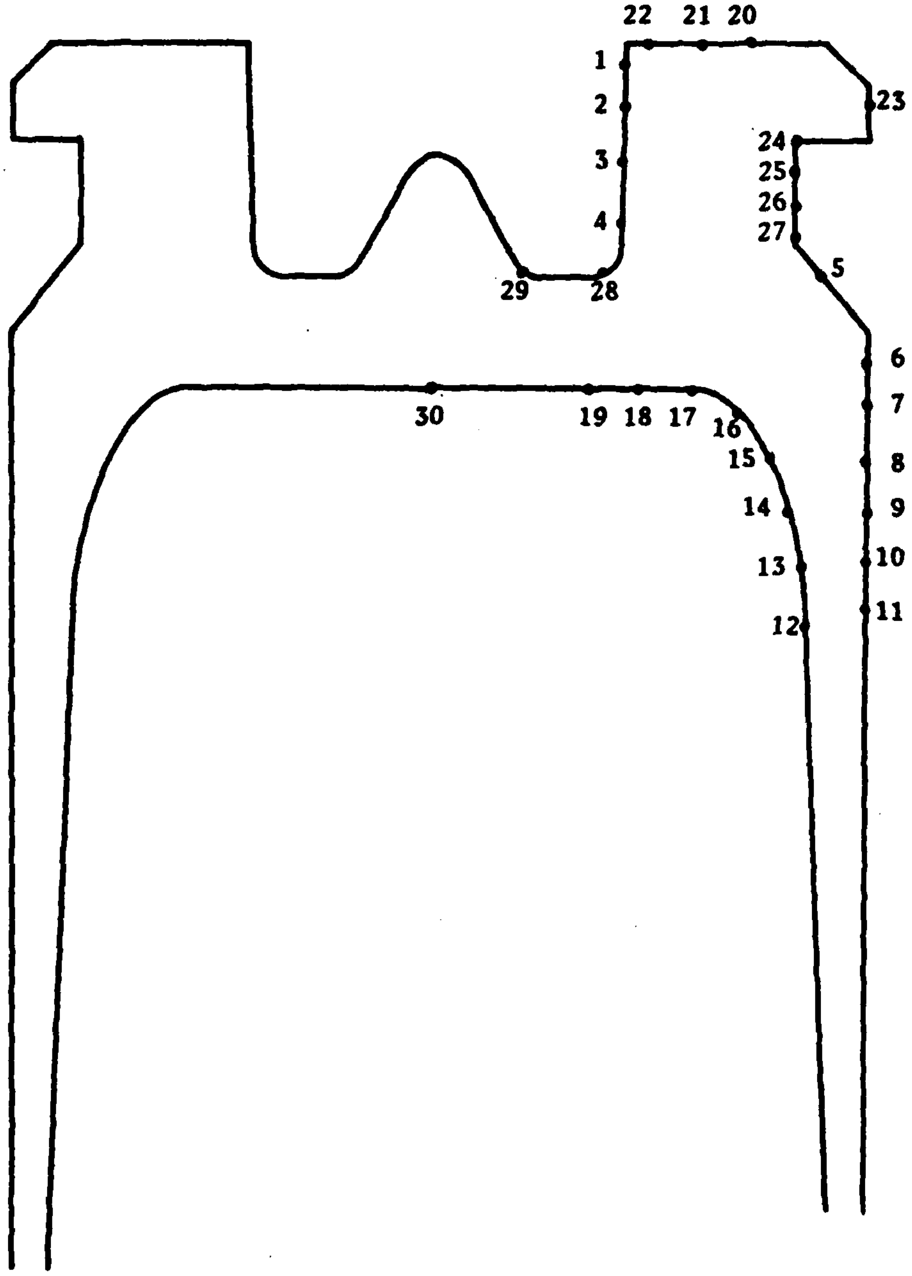
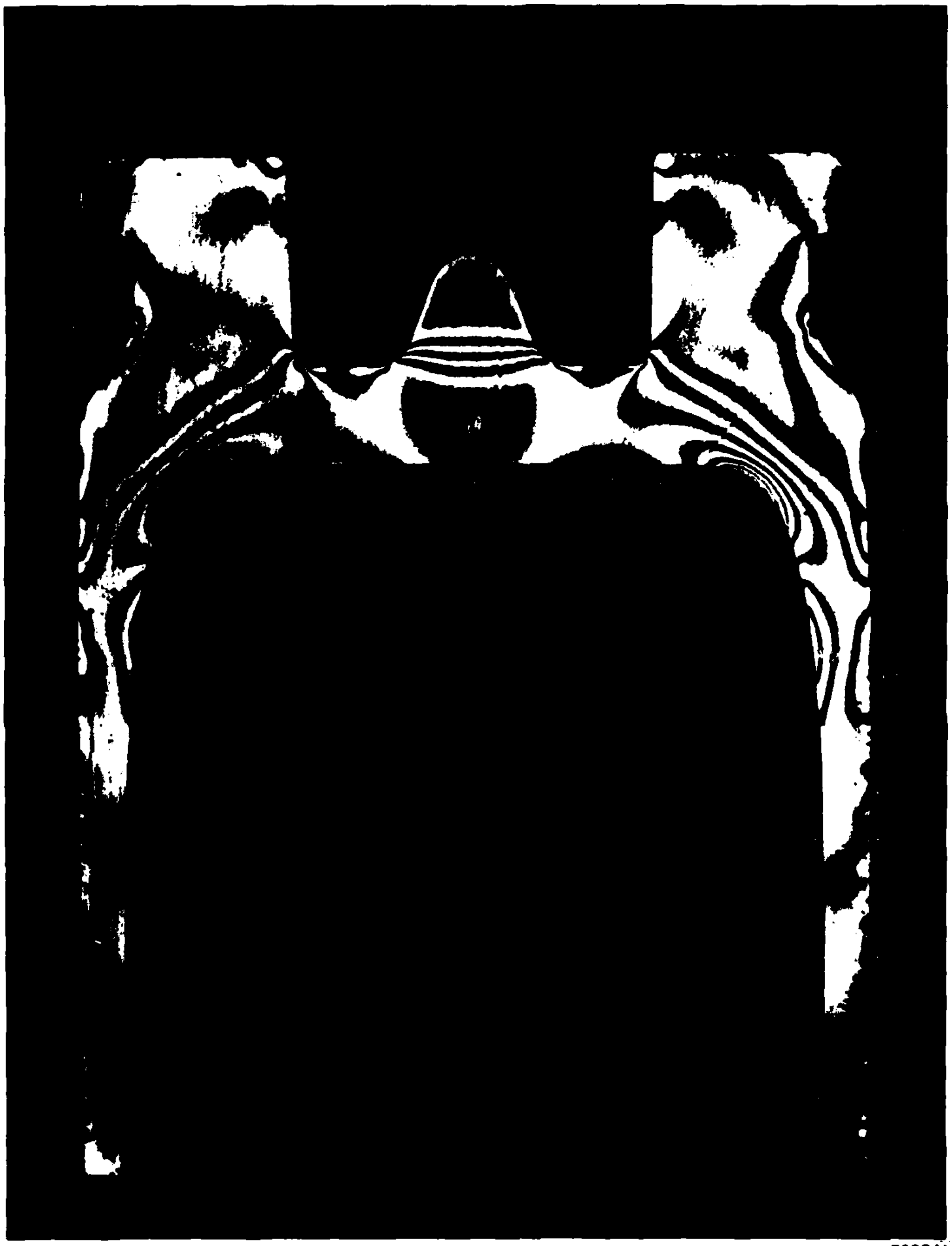


FIG 9 LOCATION OF SUB SLICES CUT FROM THE LONGITUDINAL SLICE



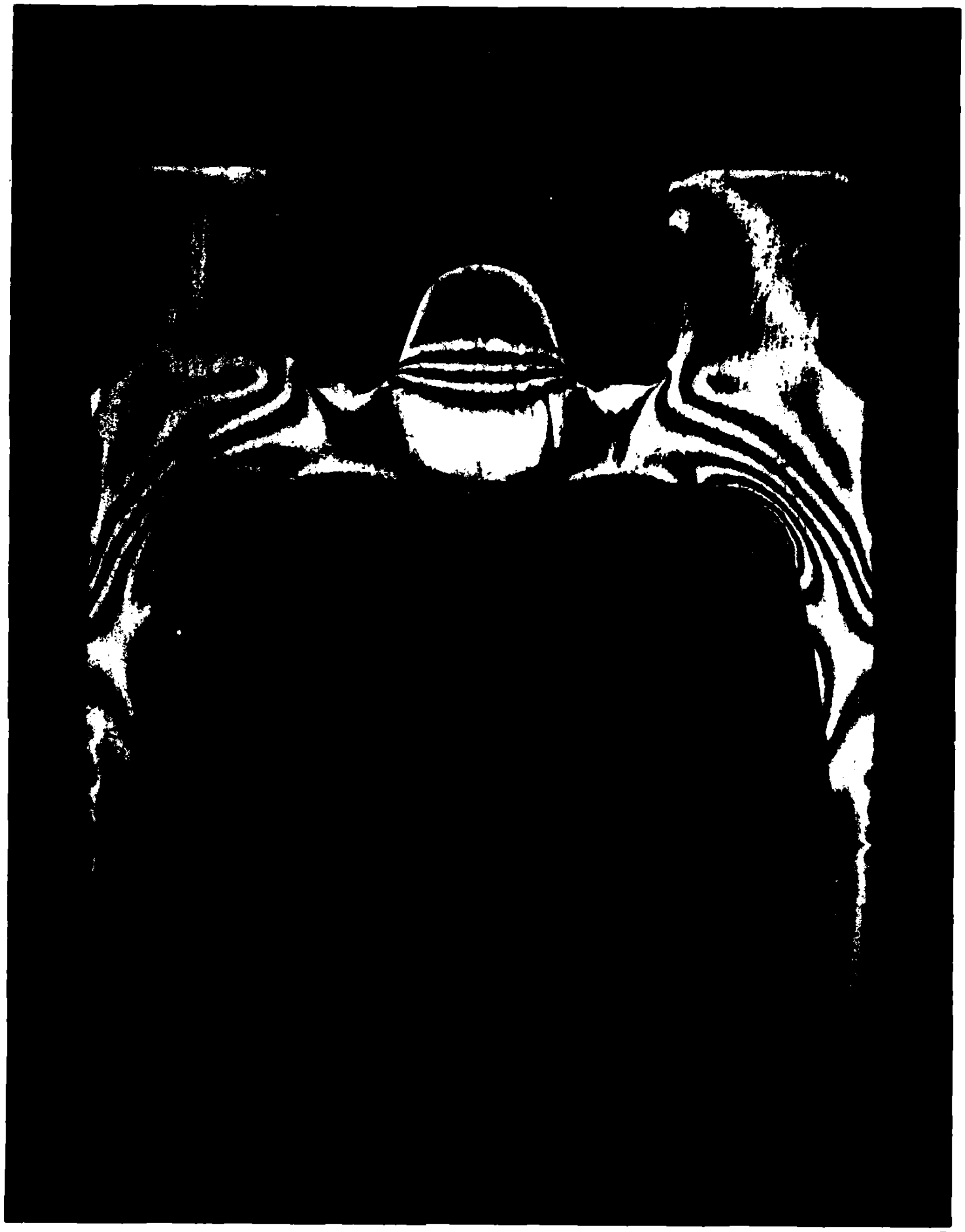
NOTE: POSITION NO 31 IS ON EDGE OF FIRE HOLE

FIG 10 LOCATION OF POSITIONS ON MODEL AT WHICH STRESSES WERE DETERMINED



7022AL

FIG 11 - PHOTOELASTIC STRESS PATTERN - LONGITUDINAL SLICE A
MODEL No 1



7021DR

FIG 12 - PHOTOELASTIC STRESS PATTERN - LONGITUDINAL SLICE B
MODEL No 2

7022AW

FIG 13 - PHOTOELASTIC STRESS PATTERN - LONGITUDINAL SLICE A
MODEL No 3

7022D

FIG 14 - PHOTOELASTIC STRESS PATTERN - LONGITUDINAL SLICE A
MODEL No 4

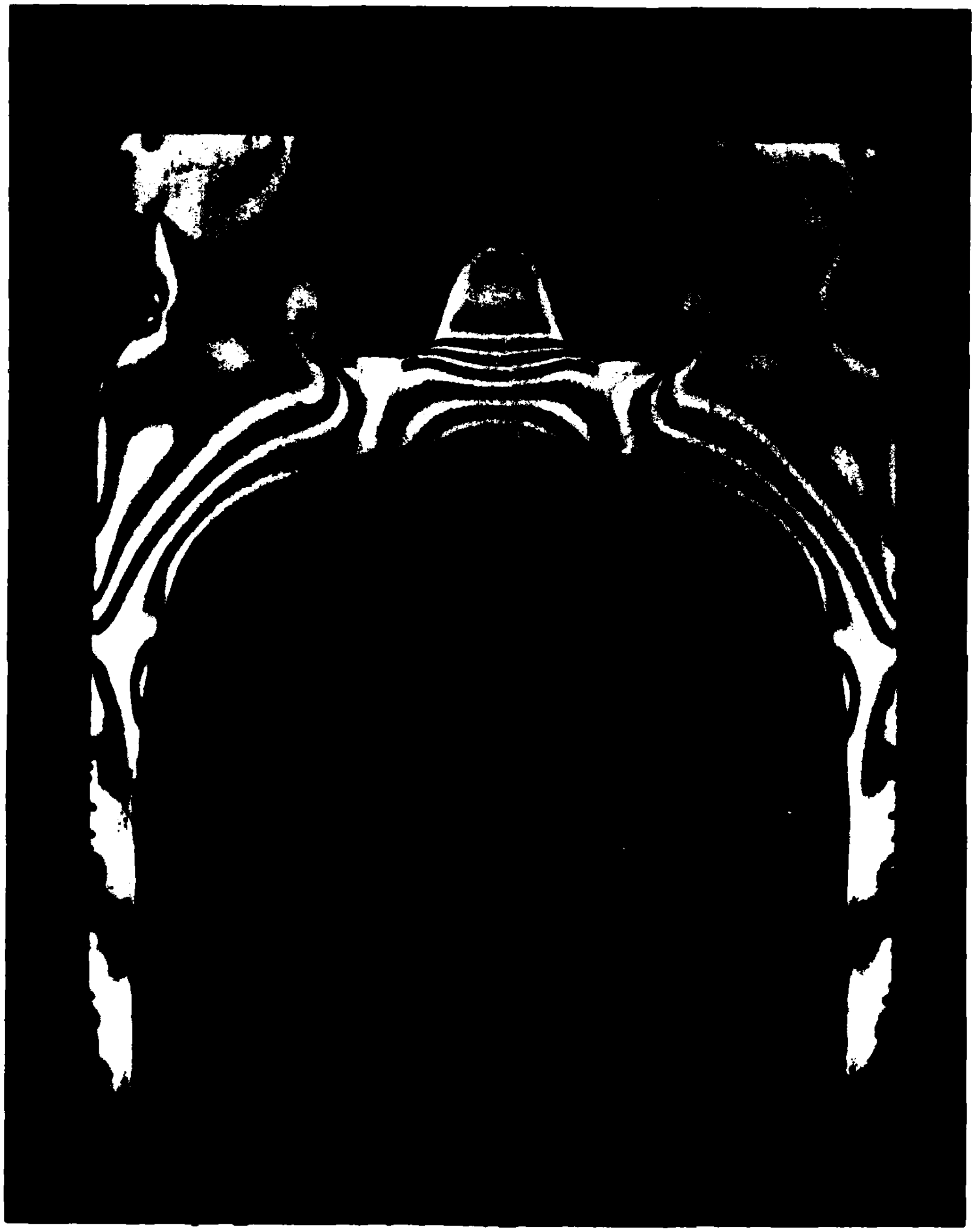


FIG 15 - PHOTOELASTIC STRESS PATTERN - LONGITUDINAL SLICE A
MODEL No 5

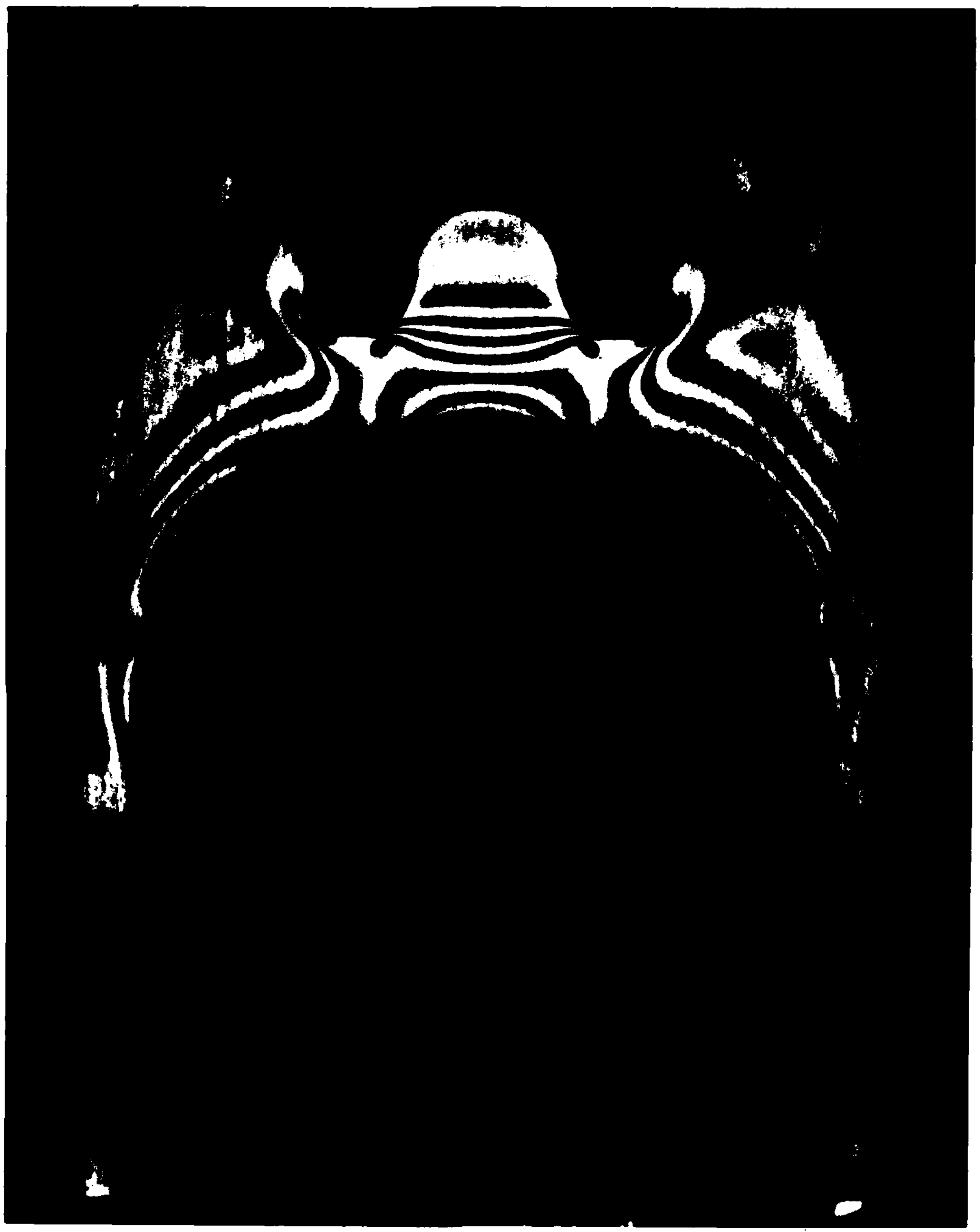


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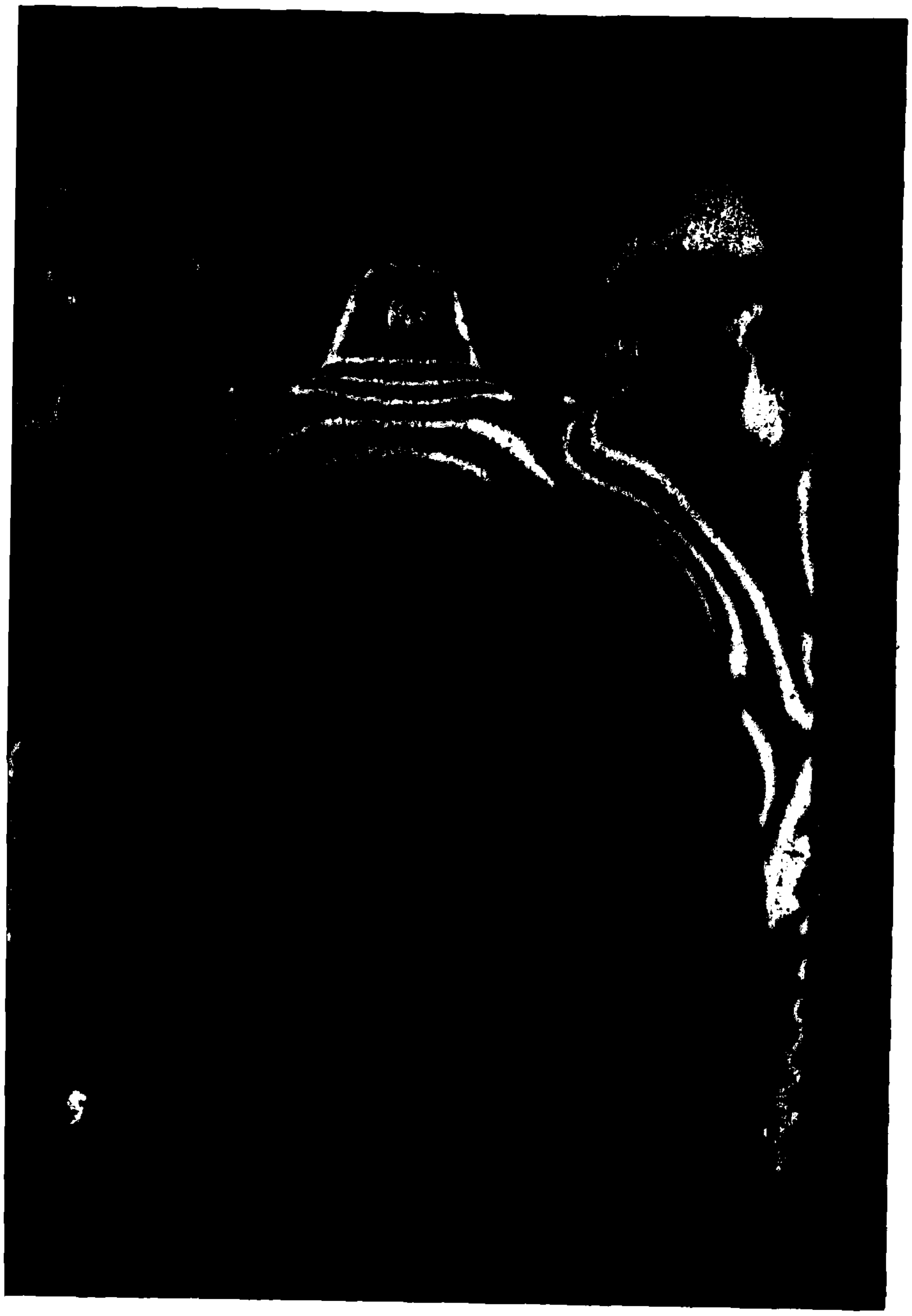
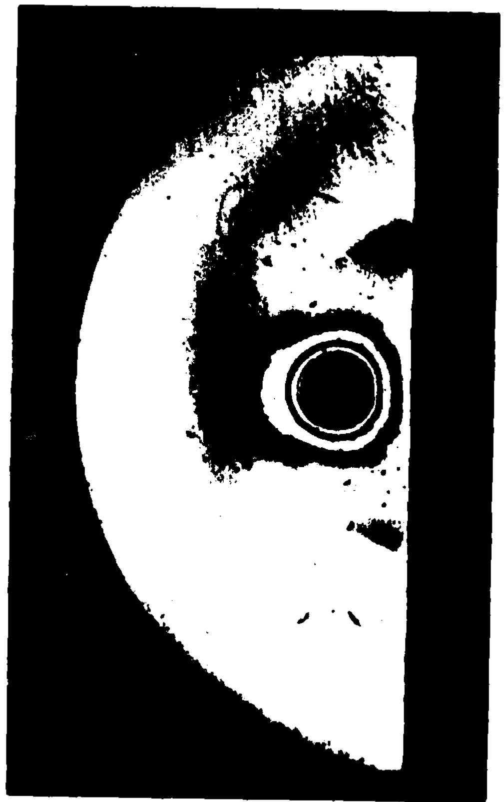
FIG 16 - PHOTOELASTIC STRESS PATTERN - LONGITUDINAL SLICE A
MODEL No 6

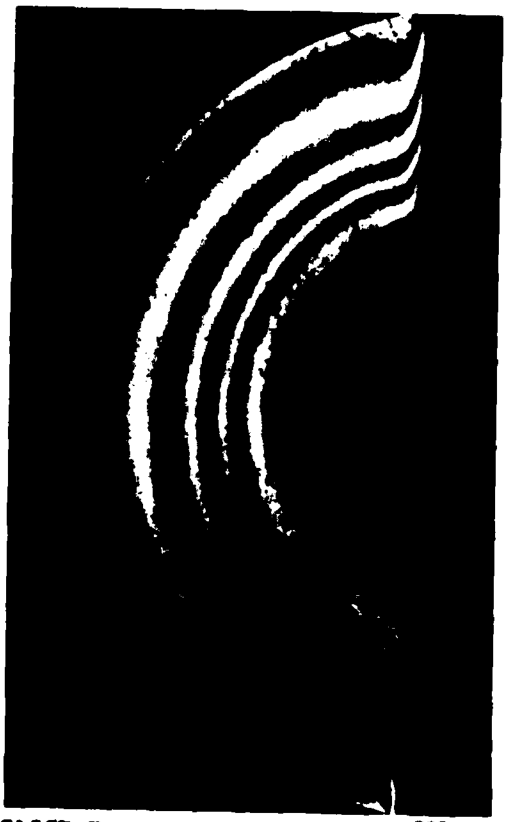


PHOTOELASTIC STRESS PATTERN - LONGITUDINAL SLICE A
MODEL No 7

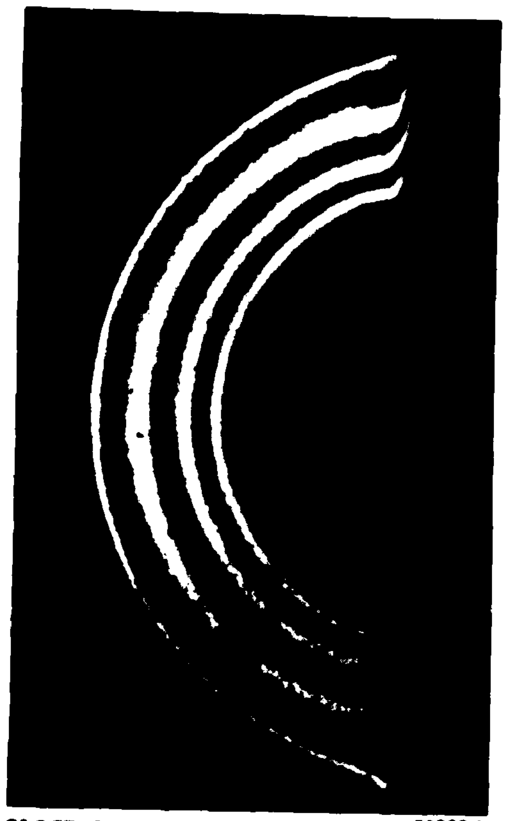
SLICE G 7022DQ



SLICE H 7022DQ



SLICE E 702.DP



SLICE F 7022DO

FIG 18 TYPICAL PHOTOELASTIC PATTERNS IN SLICES THROUGH HEAD

SLICE D 7022DZ SLICE B 7022DY SLICE C 7022DX

FIG 19 TYPICAL PHOTOELASTIC PATTERNS IN SLICES B, C AND D

TABLE 1 - STRESSES IN CARTRIDGE CASE

MODEL NO 1

Pos No	σ_r (kPa)	σ_h (kPa)	σ_t (kPa)	β (kPa)	Pos No	σ_r (kPa)	σ_h (kPa)	σ_t (kPa)	β (kPa)
1	-207	76	-76	248	17	-207	372	579	703
2	-207	90	-206	296	18	-207	152	255	448
3	-207	172	-145	352	19	-207	172	186	386
4	-207	159	-145	338	20				
5	0	62	331	303	21				
6	0	97	262	228	22				
7	0	145	262	228	23	0	145	0	145
8	0	296	69	269	24	0	97	262	228
9	0	483	262	421	25	0	97	172	152
10	0	614	455	558	26	0	62	262	241
11	0	724	524	648	27	0	62	393	365
12	-207	510	-76	662	28	-207	448	448	665
13	-207	489	-145	669	29	-207	510	448	689
14	-207	448	55	572	30	-207	317	317	524
15	-207	462	317	607	31	-207	634	-34	779
16	-207	434	710	813					

Note: Position numbers are detailed in Fig 10

Model pressures 207 kPa internal
0 kPa external

TABLE 2 - STRESSES IN CARTRIDGE CASE

MODEL NO 2

Pos No	σ_r (kPa)	σ_h (kPa)	σ_t (kPa)	β (kPa)	Pos No	σ_r (kPa)	σ_h (kPa)	σ_t (kPa)	β (kPa)
1	-207	110	-207	317	17	-207	296	317	510
2	-207	193	-76	352	18	-207	214	124	386
3	-207	131	76	296	19	-207	131	55	310
4	-20	165	76	324	20	0	138	69	117
5	0	83	131	117	21	0	172	69	152
6	0	97	131	117	22	0	269	0	269
7	0	83	193	165	23	0	124	14	124
8	0	145	131	138	24	0	145	69	124
9	0	303	131	262	25	0	145	0	145
10	0	524	262	455	26	0	145	69	124
11	0	689	524	634	27	0	145	131	138
12	-207	538	131	648	28	-207	379	379	586
13	-207	476	290	614	29	-207	441	379	620
14	-207	524	579	758	30	-207	248	248	455
15	-207	593	710	862	31	-207	579	-76	731
16	-207	448	579	731					

Note: Position numbers are detailed in Fig 10

Model pressures 207 kPa internal
0 kPa external

TABLE 3 - STRESSES IN CARTRIDGE CASE

MODEL NO 3

Pos No	σ_r (kPa)	σ_h (kPa)	σ_t (kPa)	β (kPa)	Pos No	σ_r (kPa)	σ_h (kPa)	σ_t (kPa)	β (kPa)
1	-207	83	76	248	17	-207	538	579	765
2	-207	124	-138	303	18	-207	345	317	538
3	-207	145	-207	352	19	-207	283	255	476
4	-207	179	-138	358	20				
5	0	14	393	386	21				
6	0	90	262	228	22				
7	0	241	193	221	23	0	172	0	172
8	0	469	131	421	24	0	90	262	228
9	0	696	131	641	25	0	90	324	290
10	0	717	131	662	26				
11	0	641	69	607	27	0	90	655	614
12	-207	517	-138	689	28	-207	517	517	724
13	-207	421	-76	572	29	-207	448	448	655
14	-207	386	-207	593	30	-207	427	-76	579
15	-207	427	-186	552	31	-207	627	-76	779
16	-207	579	710	855					

Note: Position numbers are detailed in Fig 10

Model pressures 207 kPa internal
0 kPa external

TABLE 4 - STRESSES IN CARTRIDGE CASE

MODEL NO 4

Pos No	σ_r (kPa)	σ_h (kPa)	σ_t (kPa)	β (kPa)	Pos No	σ_r (kPa)	σ_h (kPa)	σ_t (kPa)	β (kPa)
1	-207	214	-76	372	17	-207	358	448	614
2	-207	248	-14	393	18	-207	241	186	421
3	-207	214	-14	365	19	-207	179	124	358
4	-207	214	-76	372	20	0	159	69	138
5	0	97	179	152	21	0	207	131	179
6	0	97	131	117	22	0	90	200	172
7	0	83	200	172	23	0	90	28	83
8	0	159	131	145	24	0	124	28	110
9	0	310	69	283	25	0	124	28	110
10	0	614	393	538	26	0	97	28	83
11	0	786	586	710	27	0	97	131	117
12	-207	627	186	724	28	-207	448	448	655
13	-207	558	317	676	29	-207	538	476	717
14	-207	565	579	779	30	-207	345	341	552
15	-207	538	779	889	31	-207	620	-7	758
16	-207	441	710	813					

Note: Position numbers are detailed in Fig 10

Model pressures 207 kPa internal
0 kPa external

TABLE 5 - STRESSES IN CARTRIDGE CASE

MODEL NO 5

Pos No	σ_r (kPa)	σ_h (kPa)	σ_t (kPa)	β (kPa)	Pos No	σ_r (kPa)	σ_h (kPa)	σ_t (kPa)	β (kPa)
1	-207	138	-76	303	17	-207	476	317	614
2	-207	214	-138	393	18	-207	496	214	614
3	-207	214	-76	303	19	-207	386	317	558
4	-207	172	7	324	20				
5	0	34	262	248	21				
6	0	103	131	117	22				
7	0	117	193	165	23	0	124	0	124
8	0	172	145	159	24	0	124	131	124
9	0	303	131	262	25	0	124	131	172
10	0	483	131	434	26	0	0	262	262
11	0	745	393	648	27	0	0	372	372
12	-207	572	55	689	28	-207	579	579	786
13	-207	586	186	683	29	-207	379	317	558
14	-207	545	386	683	30	-207	684	648	855
15	-207	565	386	696	31	-207	634	-14	758
16	-207	455	345	614					

Note: Position numbers are detailed in Fig 10

Model pressures 207 kPa internal
0 kPa external

TABLE 6 - STRESSES IN CARTRIDGE CASE

MODEL NO 6

Pos No	σr (kPa)	σh (kPa)	σt (kPa)	β (kPa)	Pos No	σr (kPa)	σh (kPa)	σt (kPa)	β (kPa)
1	-207	117	-76	283	17	-207	331	255	503
2	-207	138	-76	303	18	-207	248	186	427
3	-207	152	-76	310	19	-207	283	186	448
4	-207	145	55	317	20	0	117	0	117
5	0	69	131	110	21	0	152	0	152
6	0	83	131	117	22	0	214	69	186
7	0	117	131	124	23	0	124	0	124
8	0	186	103	165	24	0	103	69	90
9	0	290	0	290	25	0	103	69	90
10	0	489	262	427	26	0	69	131	110
11	0	738	524	662	27	0	69	269	234
12	-207	565	255	676	28	-207	579	579	786
13	-207	496	214	614	29	-207	379	317	558
14	-207	503	448	683	30	-207	620	620	827
15	-207	448	448	655	31	-207	627	-76	779
16	-207	365	317	552					

Note: Position numbers are detailed in Fig 10

Model pressures 207 kPa internal
0 kPa external

TABLE 7 - STRESSES IN CARTRIDGE CASE

MODEL NO 7

Pos No	σ_r (kPa)	σ_h (kPa)	σ_t (kPa)	β (kPa)	Pos No	σ_r (kPa)	σ_h (kPa)	σ_t (kPa)	β (kPa)
1	-207	69	-207	276	17	-207	379	345	572
2	-207	103	-207	310	18	-207	358	331	552
3	-207	131	-145	310	19	-207	324	331	531
4	-207	172	-76	331	20				
5	0	62	131	110	21				
6	0	69	131	110	22				
7	0	62	234	207	23	0	124	0	124
8	0	110	234	200	24	0	48	131	117
9	0	179	186	186	25	0	48	159	138
10	0	296	131	255	26	0	0	324	324
11	0	434	131	386	27	0	0	524	524
12	-207	496	-76	648	28	-207	448	448	655
13	-207	545	124	648	29	-207	255	186	434
14	-207	545	317	669	30	-207	462	462	669
15	-207	414	386	607	31	-207	579	76	731
16	-207	379	386	593					

Note: Position numbers are detailed in Fig 10

Model pressures 207 kPa internal
0 kPa external

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16. Abstract

This report details the results of an investigation into the stress distribution in the head of a 7.62 mm NATO cartridge case using a three dimensional photoelastic stress freezing technique.

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